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BOOK OF ABSTRACTS

5th Annual Water Efficiency Conference
5-7 September 2018
University of Aveiro, Portugal

watef
Conference of the Water Efficiency Network

Proceedings of the 5th Water Efficiency Conference 2018

Date: 5-7 September, 2018
Venue: University of Aveiro, Portugal

Citation: {Authors surname, Initials…} (2018), {Paper title}, Silva-Afonso, A and Rodrigues-Pimental, C. (Eds.), *Proceedings of the Water Efficiency Conference 2018*, 5-7 September, Aveiro PORTUGAL: WATEF Network/University of Bath

ISBN-13: 978-0-86197-198-5. ISBN-10: 0-86197-198-1

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ENERWAT project: some preliminary results

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ABSTRACT

Water and energy are two linked important resources and its use efficiency must be profoundly studied. On the other hand, it is believed that there are significant differences between the pattern of water and energy consumption in rural and urban areas, whose influencing factors require study too. Several research state a large difference in urban and rural household water consumption pattern. However, rural household's consumptions are under-researched compared to urban residential consumptions. This paper aims to provide some preliminary results of a research project named ENERWAT, supported by the Portuguese Science and Technology Foundation.
One of the parts of the referred project was the design, application and results analysis of a survey, in order to find the main differences in the water and energy consumptions at the end-use level, and the factors that influence it in urban and rural households. A total of 245 households participated in the research during the year of 2016 (urban: 110 dwellings) and (rural: 135 dwellings), responding to questions such as their family composition, dwellings characterization, water and energy consumption habits and conservation behaviors of these resources. Some of the obtained results will be here provided.

Key-words: energy to water nexus, enerwat project

1. INTRODUCTION

In a time where scarce resources and climate change are a concern, it is important to define water and energy efficiency strategies that minimize the damaging impact on the environment. It is therefore necessary to develop research work to quantify and characterize consumptions, in order to define strategies for the water and energy rational use. Water and energy systems have been treated independently. However, the consumption of water directly affects the consumption of energy, and therefore those consumptions are closely related. It is the so-called water-energy nexus, whose integrated study may lead to the identification of new solutions for saving these resources.
Human beings not only consume water directly, but also use it in food production, personal hygiene, sanitation and many other industrial and domestic uses, where energy consumption is also implicit. Since water is a strategic resource for the development of a country, its efficient use must be ensured, providing not only its preservation, but also energy, financial and environmental savings [1]. On the other hand, the growing demand for water, driven by population growth and increasing quality of life requirements has also led to increased energy

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consumption. There is indeed an interdependence between energy and water that becomes more complex as the energy crisis and the impacts of climate change intensifies and contribute to changes in water and energy consumption patterns [2].
Water-energy nexus has thus been recognized as a comprehensive concept to improve management practices in the water and energy sectors [3,4]. In this context, the relationship of interdependence between these two essential resources is receiving increasing attention, both from the scientific community and from the community in general.
The knowledge about the most relevant factors influencing the domestic, water and energy consumptions is a fundamental tool for efficient planning, operation and maintenance of their distribution and availability [5]. Portugal is an importing country of fossil fuels, which makes it dependent on energy resources.
Efficient use of energy is a key to building sustainability and is one of the priorities of European energy policy.
In 2013, the residential sector accounted for 16.7% of final energy consumption, 27.2% of which consisted of electricity consumption. In this context, this sector presents a greatest potential to implement energy efficiency measures [6]. In Portugal, there are some emerging ideas about this subject. However, there are still large gaps in information and the distinction between consumption patterns in rural and urban environments is not known. Concerning the Portuguese regulations, there has been some concern in the interconnection between the energy efficiency in buildings and water efficiency. The integration of the efficiency of household appliances for the use of water in the determination of the energy performance of buildings through the National Energy Certification System (SCE) is already a reality. However, further work is still needed in this area.
In order to recommend strategies for water and energy conservation, it is necessary to characterize domestic consumption and also to collect information about socio-demographic characteristics and housing, as well as household's consumption patterns. Research work has already been developed in this domain by Matos, C. [7, 8]. It is expected that there are significant differences between water consumption patterns and, consequently, energy consumption in urban and rural areas, but these differences are not yet evaluated. This analysis is of extreme importance and has been referred to as essential for the future planning and delineation of strategic-political considerations. These differences are influenced by several factors that need to be identified.
It was with this concern that the ENERWAT project was developed at the University of Trás-os-Montes and Alto Douro, counting on the participation of researchers from different areas. The project aims to characterize the energy consumption associated with domestic water consumption in rural and urban areas, identifying the factors influencing these consumptions. To achieve these goals, the project includes user surveys and *in situ* measurements of dwellings located in both types of environments and the installation of an innovative on-site monitoring system.
It is also intended to create a simulator that will help those who are going to build a new housing to opt for solutions that lead to the consumption of less water and consequently less energy and, for those who already have a home, to choose new solutions that lead to the reduction of these consumptions. At the same time, for each simulated case, a cost analysis will be carried out that will allow the user to make decisions. It also aims to create a manual of good practices and improvement solutions that contribute to the reduction of water and energy consumptions.

2. THE PROJECT

The following general tasks were defined for the project development and the pursuit of the intended objectives:

1. State of the art;
2. Design and application of a survey, data treatment and analysis;
3. On-site instrumentation and monitoring for the acquisition of water and energy consumption, in rural and urban environments;
4. Definition of a consumption simulator;
5. Economic analysis;
6. Practical recommendations and dissemination of results.

A brief description of tasks 2 and 3 and the main results obtained so far are presented below.

3. SURVEY APPLICATION

The survey was applied to 110 urban dwellings and 135 rural dwellings, during the year 2016, in the district of Vila Real. This survey allowed to collect diverse information that are grouped and summarized in Table 1. It integrated 74 questions grouped into 6 categories. All of these questions were based on the state of art. This survey was prepared using an online tool called "onlinepesquisa.com" and it was applied door-to-door between December 2016 and January 2017. The fact that it was applied door-to-door allowed a high number of valid answers given the fact that the questions were immediately clarified. Only one person per household responded to the survey.

Table 1. Categories of the issues addressed in the survey

Categories	Collected information
1. Characterization of the household	Number of members; age; qualifications; professional activity; family income.
2. Dwelling characterization	Environment location (rural or urban); area and typology of housing.
3. Energy consumption	Energy source used; electrical equipment; total energy consumption.
4. Water consumption	Type of water supply, number and duration of baths / showers, total water consumption.
5. Clothes washing	Washing machine; class of machine efficiency; number and duration of uses; hand wash.
6. Dish washing	Dishwasher; class of machine efficiency; number and duration of dishwasher use; hand wash.

Regarding water and energy consumption, since most households were unable to provide the exact data of the monthly bill in relation to the year 2016, it was questioned, what was the range of values that were paid per month of water, electricity and natural gas consumptions. For the other sources of energy used (firewood, pellets, briquettes, diesel, bottled LPG, etc.) the annual costs were requested. After having the answers of all household consumption, monthly costs (€) (in the case of water, electricity and natural gas) were converted into monthly consumption (m^3, kWh), based on the EMARVR collection form and EDP Vila Real (local entities responsible for the distribution of water and energy (electricity and natural gas) respectively). In the particular case of electric power, the normal and double tariff consumption was calculated separately.

The mode of monthly and annual average consumption was calculated for rural and urban environments (Figures 1, 2, 3 and 4). For the remaining energy sources, the annual consumption value (toe - tonnes of oil equivalent) was calculated using the amount spent (€) and quantity (kg, l) using the conversion factors available for the various types of energy.

As a brief analysis of the results, it was possible to conclude that the annual water consumption was higher in the urban environment, with values between 6 and 16 m^3, corresponding to 70% of the analysed cases (Figure 1). In what concerns to the natural gas consumption, it was observed, as expected, that its use has no significance in the rural environments, given the fact that these areas are not served by the respectively municipal infrastructures (Figure 2). With regard to annual average of electric energy consumptions, it is highlighted the predominance of use of simple tariffs when compared with the double tariff (Figures 3 and 4).

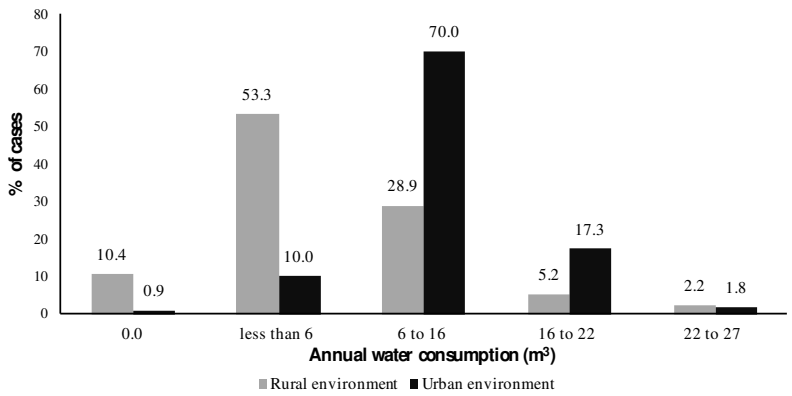

Fig 1. Annual average of water household consumption in rural and urban areas

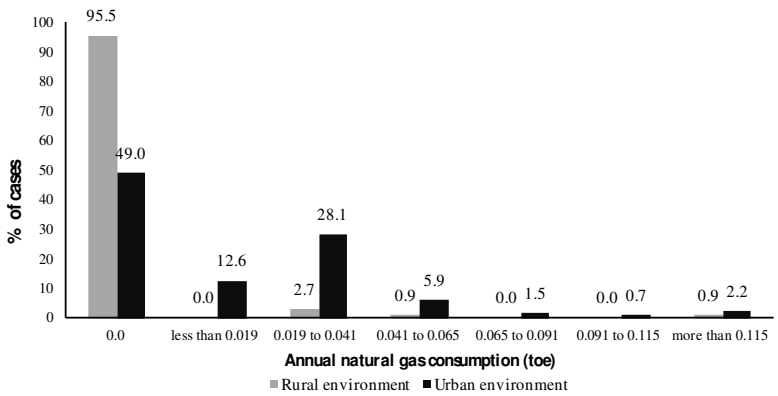

Fig 2. Annual average of natural gas consumption in rural and urban areas

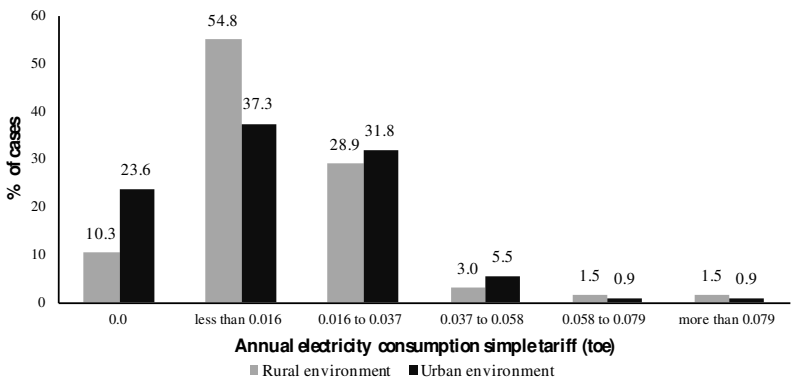

Fig 3. Annual average of electric energy (simple tariff) consumption in rural and urban areas

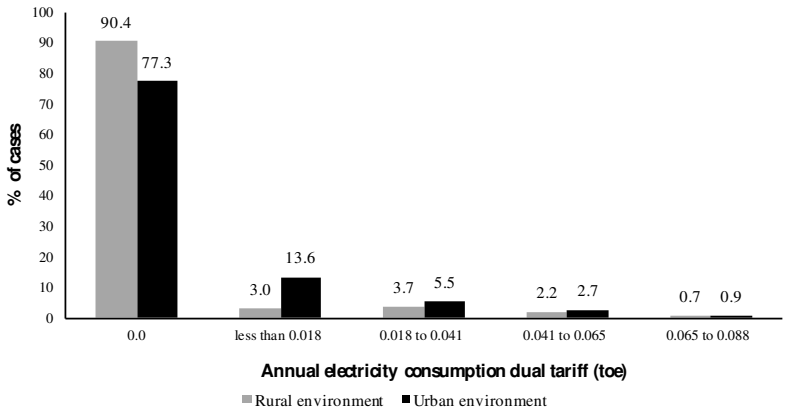

Fig 4. Annual average of electric energy (double tariff) consumption in rural and urban areas

The variables that may or may not influence the consumption of these resources in both environments are being analysed through an in-depth statistical analysis of the collected data. The final objective of this task is to obtain, if possible, the correlation between water and energy consumption in rural and urban environments and to know which factors influence the differences in the consumptions.

4. INSTRUMENTATION AND MONITORING

It is intended with the instrumentation and monitoring of dwellings in rural and urban environment to quantify the water consumption and associated energy consumption. In addition to the measurements, the characterization of housing and the behaviour patterns of the members are also carried out.
Water consumption monitoring is carried out on all existing water use devices (wash basin, shower, bidet, toilet, dishwasher, washing machine and dishwasher) and also on the water meter. Energy consumption is quantified by monitoring the counters of their respective energy sources, namely electricity and gas.
The instrumentation and monitoring of the water consumption devices was carried out by placing magnets and magnetic sensors on the faucets and water flushing systems of the flushing cisterns and also on the placement of voltage sensing sensors between the washing machines and the respective sockets feed [9].
The placement of magnetic sensors on the taps made it possible to check the opening (ON) and the lock (OFF) and whether they were charging hot water, cold water or hot / cold water (Fig. 5).

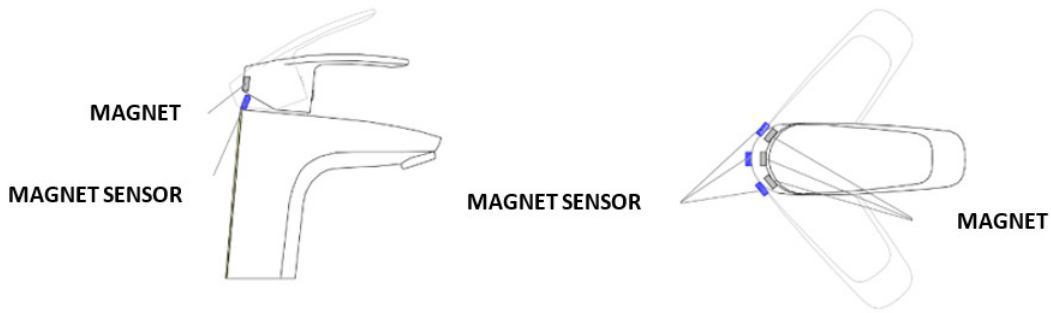

Fig. 5. Placement of sensors on taps (adapted from [9])

The data collected by the different devices are stored in a Single Board Computer (SBC), installed in each room where there are devices for consumption measurement. In the water, gas and electricity meters, cameras were used to capture images of the values recorded in the counters whenever there is a change in the digits, which corresponds to a change in consumption. Subsequently, it is necessary to compare the results obtained by triggering the sensors with those obtained by changing the digits shown in the meter display. This comparison will make possible to identify the water consumption devices used, the consumption of water (hot or cold), the period of use and the source of energy used (electricity or gas) and their consumption.
Figure 6 shows an example of the type of results that can be obtained through the instrumentation and monitoring of household consumption. The hourly and hourly average values for water and energy consumption (electricity and gas) obtained for a day of the week in one of the dwellings under study are presented.

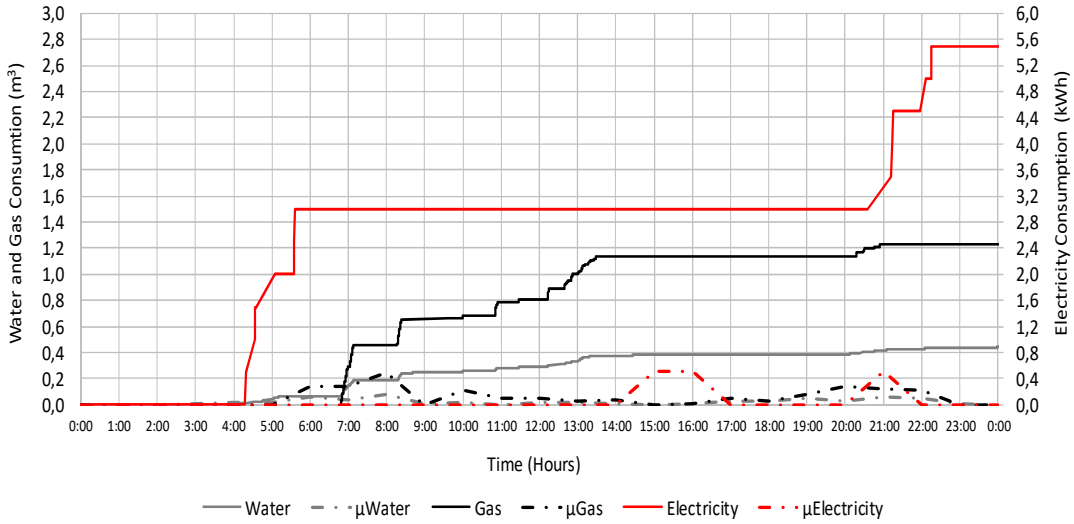

Fig. 6. Hourly and average hourly (µ) of water, electricity and gas consumptions

5. CONCLUSIONS

The preliminary results revealed by the surveys indicate differences between domestic consumption of water, electricity and natural gas, between rural and urban areas. There appears to be some seasonality in the collected data. It reveals significant differences between the sociodemographic variables in the rural and urban environments. So, it is important to identify the predominant variables in the differences found in the consumption of water and energy, which analysis is in progress at the moment. In the future, it would be interesting to extend the application of the survey to other regions of the country in order to identify the main differences between the different regions.
The work developed so far allows the continuous collection of data *in situ* through a simple monitoring system. The system allows identifying the water consumption devices used, the consumption of water (hot or cold), the period of use and the source of energy used (electricity or gas) and their consumption.
The results obtained until now are available at http://enerwat.utad.pt. In the second semester of this year will also be available the consumption simulator and the manual of good practices and improvement solutions as well as all future results. In November, a seminar will be held with the dissemination of the project results.
This project will contribute to the knowledge and will allow the advancement of science in this area and also the definition of new strategies for the efficient management of water and energy resources.

ACKNOWLEDGEMENTS

This work was partially funded by project POCI-0-0145-FEDER-016730 (PTDC / AAG-REC / 4700/2014) under the name ENERWAT: Water for energy: characterization, modeling and measures for reducing domestic urban and rural consumption, funded by the Foundation for Science and Technology and co-financed by the European Regional Development Fund (ERDF) through COMPETE 2020 - Operational Competitiveness and Internationalization Program (POCI).
This work was partially supported by the FCT (Portuguese Foundation for Science and Technology) through the project PEst-OE / ECI / UI4082 / 2013 (C-MADE).

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